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THE ANALYSIS OF THE USE OF SAND COLUMN IN RECHARGE RESERVOIR AS SEAWATER INTRUSION BUFFER

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ABSTRACT. Excessive groundwater exploitation may cause groundwater emptiness and increase the seawater pressure to the land, and generate sea water intrusion. One of the efforts to buffer sea water intrusion is groundwater recharge by using recharge reservoir. When a recharge reservoir is to be built on an area with permeability coefficient of less than 10^{-5} cm/sec, it will be analyzed by using sand column model, which is put on the recharge reservoir base and directly connected to the aquifer layer. The objective of this research is to analyze the use of sand column to the amount of groundwater recharge. This research is an experimental study in the laboratory that includes the main of recharge reservoir model with and without sand column, which will result in primary data that consists of recharge entering the aquifer within various parameters: energy level differences, sand column or soil layer thickness, and sand column density. Each parameter consists of three variables. Results of this research indicated that the maximum discharge was 62.41 cm^3/sec that occurred at 0,00157 density, difference head of 37.4 cm and sand column height of 30 cm respectively. It is expected that results of this study are applicable and can developed on field, to cope with the problem of sea water intrusion.

Keywords: Recharge reservoir, sand column, sea water intrusion

INTRODUCTION

Excessive groundwater exploitation to fulfill household, hotel, hospital, industrial demands and other commercial activity have caused groundwater emptiness, which will initiate seawater intrusion. To cope with this problem, various efforts have been taken by recharging water into the ground, either by natural or artificial methods, to accelerate water absorbance. One of the methods is by using the recharge reservoir. Designed to reach the aquifer layer, this type of reservoir has the capability to absorb surface runoff more than ponds or lake, which are used more as water reservoir. However, there will be problem when the reservoir is to be built on a particular area with permeability value and absorbance power where water will be very slow in reaching the aquifer layer and may fail its function as a recharge reservoir. Therefore, it is required to study the use of sand column, which will be put on the base of the recharge reservoir and directly connected to the aquifer layer within various parameters. This method is expected to provide solution to the problem of seawater intrusion. The objective of this study is to identify the groundwater recharge due to the use of sand column.

LITERATURE STUDY

Seawater Intrusion

Seawater intrusion is a phenomenon where seawater enters the aquifer. This can be caused by various factors. Some of them are the land use changing, mangrove deforestation, population growth, and increasing industrial area near to coastline which uses groundwater to fulfill their clean water needs. Such exploitation, especially exaggerated exploitation, may cause hydraulic equilibrium changes between water and seawater pressure, causing seawater to enter the land. Also, the characteristics of the beach and the composing rocks, as well as the groundwater fluctuation in the beach area, contribute to seawater intrusion, which is one of the cause factors of groundwater quality degradation. This can be seen by the increasing salinity of groundwater based on the chloride ion content indicated by the total dissolved density value and the groundwater conductivity. According to Husni (2010), seawater intrusion causes groundwater to change from freshwater to brackish water or even to salty water. When the groundwater fluctuation is high, the seawater intrusion probabilities are higher with decreasing groundwater condition.

According to Ashriyanti (2011), in areas near to beach or ocean, freshwater and seawater meet, and is

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called as interface. It can be projected either to the sea or to the land depending to the amount of rainfall recharge. When rainfall recharge is significantly high, the interface is projected to the sea. When the rainfall recharge is low or even none, the *interface* will be projected to the land.

Soil Permeability Coefficient

Soil permeability coefficient is the amount of water flow of each time unit passing through one area unit of aquifer section (Hadiyatmo, 2010). To determine the soil coefficient permeability precisely, it is required to use laboratory methods such as the fixed head testing, which is used for soil with coarse granule and high permeability coefficient, as well as falling head testing, which is used for soil with fine granule and low permeability coefficient.

Law of Darcy

Law of Darcy explains the capability of water to flow through the soil pores and the influencing characteristics. The speed of the flow and the quantity/ /debit of water per time unit is the proportion with the hydraulic gradient (Soedarmo and Purnomo, 2001).

$$Q = k.i.A \quad (1)$$

$$V = \frac{q}{A} = k.i \quad (2)$$

Where: q = water flow volume per time unit (cm3)
A = soil section area (cm2)
k = coefficient permeability (cm/sec)
i = hydraulic gradient
v = flow velocity (cm/sec)

Recharge Reservoir

The function of recharge reservoir

Recharge reservoir is one of reservoir types with the main function as the media to make it easier for water to be absorbed to the aquifer layer. This type of reservoir is suitable for area with shallow groundwater surface and available in wide area (Kusnaedi, 2005). According to Sudinda (2004), as the Team leader of the recharge reservoir development project in Kementrian Ristek, the basic philosophy of the development of recharge reservoir is how to minimize runoff and to increase the capability of the ground to absorb surface water. Recharge reservoir can be classified as *single purpose* reservoir, which is to control flood with a work system that increases the optimization of aquifer function and to raise the storing capacity in the aquifer layer (Broto and Susanto,2008) .

The utility of recharge reservoir includes :

1. To optimize the aquifer function and raise water storage capacity in the aquifer
2. To be functioned as flood control in upstream or runoff area.
3. To be used as water storage in dry season.

Sand Column

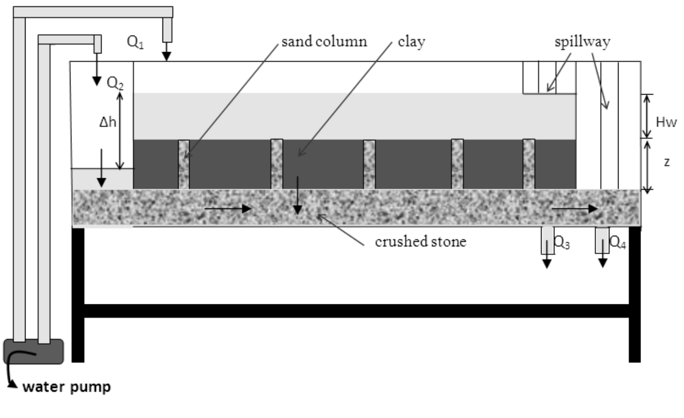

Figure 1. The concept of recharge reservoir with sand column

Sand column is a media expected to absorb the reservoir water into the aquifer layer. The traditional method is by making drilled hole in the clay layer with small permeability and refilling it with gradated sand. Sand should be flown with water efficiently without taking the fine particles (Joleha, 2001). Figure 1 shows the sketch of sand column with a principle that water coming from the surface is stored in the reservoir within certain height. Then, water is flown through the sand column in order to have sand with higher permeability, to accelerate and enlarge the recharge and filtration that water entering the aquifer layer is in clean condition.

Sand column density

Sand column density is a comparison between the surface area of sand column (A') and the surface area of recharge reservoir (A), or written in the flowing formula :

$$A' = \frac{1}{4}\pi d^2 N_{sc} \quad (3)$$

$$A = p \times l \quad (4)$$

$$\delta = \frac{A'}{A} \quad (5)$$

Where :
ƺ = sand column density
d = sand column diameter
N_{sc} = number of sand column
p = reservoir length
l = reservoir width

RESERCH METHOD

Time and Location

This study was carried out in six month period, starting from sample taking to the end of the testing in The Soil Mechanic Laboratory and Hydraulic Laboratory of Civil Engineering Department of Politeknik Negeri Ujung Pandang. Sand sample was taken from Jeneberang river Gowa district, and soil sample was taken from Tamalanrea Makassar city.

Research Procedures

This study consisted of several steps:

1. Data collecting
   Soil and sand sample was taken and instruments in the laboratory were prepared.
2. Laboratory testing
   Laboratory testing included water content testing, sieve analysis and permeability analysis. The recharge reservoir model testing was carried out without sand column and used sand column within various parameters: reservoir height, soil later thickness and sand column thickness and the number of sand columns. Each parameter consisted of 3 variables.
3. Data analysis
   Data resulted from observation to the recharge reservoir model testing with and without sand column was processed and plotted in a relationship graphic between recharge debit (Qa) with the available parameters. Based on the testing result of the physical model using the sand column, it was resulted in equation of recharge debit as the function of reservoir water height, sand column diameter, sand column height, and the difference head. In order to obtain qualified results, it was necessary to test the relationship strength between parameters and the validation to the research results.

Fig.2. Measurement of recharge entering reservoir

Fig.3. Measurement of recharge exiting aquifer

RESULTS AND DISCUSSIONS

Soil Type

The testing result of soil and sand sample based on the four soil classification system indicated that the soil used in this research was silt with low plasticity and the sand was coarse.

Sand Column Height of 30 cm

Figure 4 shows 37.4 cm increasing debit at 30.2 cm energy level difference. Based on this figure, the difference of recharge debit is significant from density 0 to 0.0157. At density = 0, the minimum groundwater recharge debit was 0.50 cm^3/sec and maximum was 0.618 cm^3/sec. At density=0.0057, the minimum groundwater recharge was 15.49 cm^3/sec and maximum was 19.19 cm^3/sec. At density = 0.010, the minimum groundwater recharge debit was 32.06 cm^3/sec and maximum was 39.72 cm^3/sec. At density=0.0157, the minimum groundwater recharge debit was 50.4 cm^3/sec and maximum was 62.41 cm^3/sec.

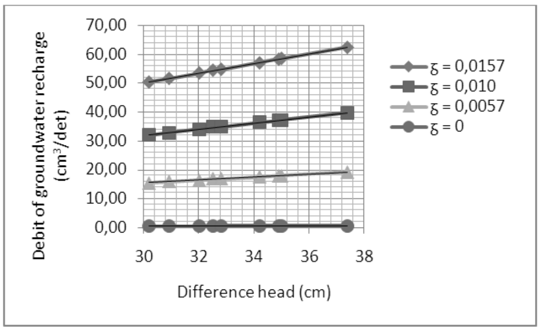

Fig. 4. The relationship of debit entering the aquifer and difference head at z =30 cm

Sand Column Height of 32.5 cm

Figure 5 shows the increasing debit at energy difference level of 32.4 cm to 40.3 cm. Similar to Figure 4, Figure 5 shows significant groundwater recharge difference at density 0 to 0.0157. At density = 0, minimum groundwater recharge debit was 0.497 cm^3/sec and maximum was 0.615 cm^3/sec. At density = 0,0057, the minimum groundwater recharge debit was 15.36 cm^3/sec and maximum was 19.11 cm^3/sec. At density = 0,010, the minimum groundwater recharge debit was 31.86 cm^3/sec and maximum was 39 cm^3/sec. At density=0.0157, the minimum groundwater recharge debit was 50 cm^3/sec and maximum was 62.22 cm^3/sec.

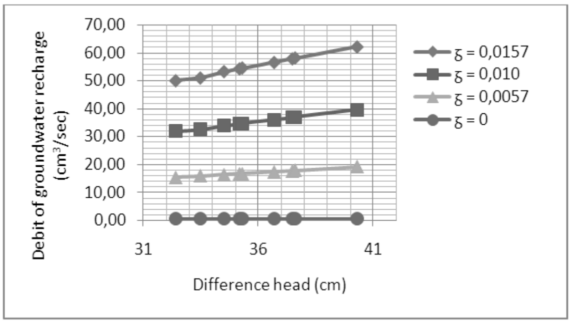

Figure 5. The relationship of debit entering aquifer and difference head at z =32.5cm

Sand Column Height of 35 cm

Figure 6 shows increasing debit of energy level difference from 34.6 cm to 42.6 cm. Such as in Figure 4 and Figure 5, Figure 6 indicates significant difference of groundwater recharge debit from density 0 to 0,0157. At density=0, the minimum groundwater recharge debit was 0.489 cm^3/sec and maximum was 0.608 cm^3/sec. At density=0.0033, minimum recharge debit was 10.09 cm^3/sec and maximum was 12.46 cm^3/sec. At density=0.0057, the minimum recharge debit was 17.44 cm^3/sec and maximum was 21.46 cm^3/sec. At density=0.0157, minimum recharge debit was 49.73 cm^3/sec and maximum was 61.21 cm^3/sec.

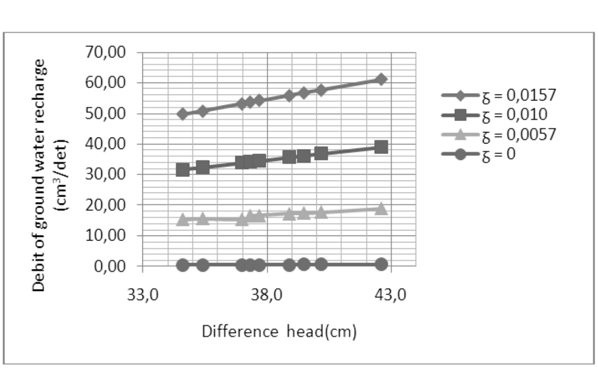

Figure 6. The relationship of debit entering aquifer and difference head at z =35 cm

Figure 4, Figure 5 and Figure 6, show the functional relationship between groundwater recharge debit and the difference head at every soil layer thickness or sand column height. The functional relationship was a linear relationship, both for recharge reservoir without sand column (density 0) and with sand column (various densities). The tendency of increasing groundwater recharge debit followed the same pattern with the increasing of energy level difference.

Based on the abovementioned explanation, it can be generally described that the average percentage difference of groundwater recharge difference due to the energy level difference at the soil layer thickness or the sand column height were 30 cm, 32.5 cm and 35 cm at all sand column density. This was due to the increasing difference head that would influence the level of increasing groundwater recharge debit. Then, it can be described that higher energy level difference would decrease the piezometrik pressure that hampered the water entry from the reservoir water, both through soil layer and sand column to the aquifer layer. Results of this study are supported by the Bernoulli Equation and Law of Darcy which show the direct proportional connection between debit and energy level difference.

CONCLUSIONS

Based on the results of this study, several conclusions can be drawn as the followings:

1. The higher the difference head and sand column density, the larger the groundwater recharge debit will be. On the contrary the thicker the soil layer or the height of the sand column, the smaller the recharge debit will be.
2. The maximum debit of 62.41 cm^3/sec occurred at 0.0157 density and 37.4 cm difference head with sand column height of 30 cm.
3. The sand column can be used in the recharge reservoir base with small permeability to buffer seawater intrusion.

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REFERENCES

Ashriyanti, H. 2011. *Kajian Kerentanan pada Wilayah Terintrusi Air laut di DKI Jakarta*. Tesis tidak dipublikasikan. FMIPA PPS Ilmu Geografi UI, Depok.

Broto, S dan Susanto, H. 2008. Perancangan Model Pendugaan Efektifitas Waduk Resapan Kota Bogor terhadap Optimalisasi Akuifer Air tanah. *Jurnal Teknik*, 29 : 220 – 227.

Djudi. 2006. *Kajian Waduk Resapan Tambakboyo, Kecamatan Ngemplak, Kabupaten Sleman,* *Propinsi DI Yogyakarta*. Tesis tidak diterbitkan. Bandung : Program Magister Teknik Sipil ITB

Hardiyatmo, H,C. 2010. *Mekanika Tanah 1*. Gajah Mada University Press, Yogyakarta

Hargono, B. 2011. *Belajar Dari Embung Tambakboyo Di Yogyakarta Untuk Mengatasi Masalah Sumber Daya Air Di Pulau-Pulau Kecil Dan Pantai*. Prosiding PIT XXVII HATHI, Ambon

Herlambang,A., Indriatmoko,R,H. 2005. Pengelolaan Air Tanah dan Intrusi Air Laut. *Jurnal Air Indonesia*, 2 : 211-225

Joleha. 2001. Analisa Drainase Vertikal Untuk Mempercepat Konsolidasi Pada Tanah Lunak. *Jurnal Natur Indonesia*. Vol. 4 No. 1

Kodoatie, R.J., Sjarief, R. 2008.*Pengelolaan Sumberdaya Air Terpadu*. Andi, Yogyakarta

Koosdaryani. 2009. Penggunaan Modifikasi Desain Sumur Resapan Sebagai Pengisian Kembali Air tanah dan Pengendalian Banjir di Kel.Sewu Surakarta. *Media Teknik Sipil*, 9: 136 – 139

Kusnaedi. 2011. *Sumur Resapan Untuk Pemukiman dan Perkotaan*. Swadaya. Jakarta.

Media Indonesia, Digilib. 17 Maret 2004. *Waduk Resapan Atasi Banjir dan Kekeringan*, (Online), (Ztp://www.mediaindonesia.com, diakses 20 Juli 2011)

Pramono, R., 1999. Permasalahan Air di Perkotaan dan Perilaku Masyarakat. *Jurnal Studi Pembangunan, Kemasyarakatan dan lingkungan*, 3 : 39-45

Putranto, T., Kusuma. 2009. Permasalahan Air tanah di Daerah Urban. *Jurnal Teknik*, 30:48 – 56

Puradimaja, D. 1997. Permasalahan Air tanah dan Peluang Risetnya. *Buletin Geologi Tata Lingkungan*, 21 : 22 – 30

Soenarto, B. 2007. Teknik Sumur Injeksi untuk Pengendalian Banjir Dan Keperluan Lain serta Berbagai Teknik Ekivalen Lainnya. *Jurnal Sumberdaya Air*, 3 : 49 – 62

Sudinda, T, W. 2004. *Simulasi Potensi Waduk Resapan Pada Akifer Tertekan Dengan Metoda Finite Difference*. Jurusan Teknik Sipil FTSP Trisakti, Jakarta

Sunjoto. 2011. *Teknik Drainase Pro-Air*. Proceeding Seminar Nasional-1 BMPTTSSI - KoNTekS 5, Medan

Sunjoto. 2012. *Subsurface Hydrology*. Post Graduate Program Department of Civil and Environmental Engineering Faculty of Engineering Gadjah Mada University, Yogyakarta

Tresnadi, H. 2007. Dampak Kerusakan yang Ditimbulkan Akibat Pengambilan Air tanah yang Berlebihan. *Jurnal Alami*, 12 : 76 – 81

Wahyudi, H. 2009. Kondisi dan Potensi Dampak Pemanfaatan Air tanah di Kabupaten Bangkalan. *Jurnal Aplikasi*, 7 : 14 – 19.